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SALTCEDAR AND SALINITY
ON THE UPPER RIO GRANDE

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This is a story of a river, a tree, a county and a country. The river is the Rio Grande, the Rio Bravo del Norte of the Mexicans. The tree is the tamarisk (Tamarix pentandra) or salt cedar as it is called in the Southwest. The county is Hudspeth County, Texas, which lies downstream from the city and county of El Paso, Texas. This paper will discuss that part of Hudspeth County which lies in the irrigable portion of the Rio Grande between the El Paso County line and Fort Quitman, where mountains on both sides of the river close in to form a box canyon, terminating in what is referred to in the United States as the Upper Rio Grande. The country is Mexico. This report concerns that part of Mexico which lies below Ciudad Juarez and constitutes the irrigable valley in Mexico lying between Ciudad Juarez and the mountains previously referred to at Fort Quitman.

The River

The Rio Grande is a typical example of a river of arid and semi-arid regions. It rises in the snow-covered mountains of the State of Colorado and runs in a southerly direction through the central part of New Mexico until it reaches El Paso, Texas, where it changes its direction in a southeasterly swing.

Drainage area of the Upper Rio Grande is about 34,000 square miles (88,000 square kilometers). Over 99 percent of its water supply derives from snow melt in the high mountains of Colorado and New Mexico. Over a million people inhabit the area, most of them concentrated in rapidly expanding urban centers of Albuquerque, New Mexico; El Paso, Texas; and Ciudad Juarez, Chihuahua, Mexico, the latter city having the largest population (over 500,000). Arid lower reaches of this section of the river have average annual rainfalls of only about eight inches (200 millimeters).

The upper river is divided into three natural areas. That part lying in Colorado is known as the San Luis Valley. It is bounded on three sides by mountains and contains an irrigated area of approximately 650,000 acres (260,000 hectares). It is by far the largest irrigated area in the upper river. Its proximity to the mountains whose snow melt causes the birth of the river gives it first and least salty use of the river valley's water supply. Its sandy loam is excellent for the raising of potatoes, for which it is noted.

The middle reaches of the river, through the northern and central sections of New Mexico, are confined, to a large extent, in canyons and in narrow valleys. Stream-bed slope is mild and accumulation of silt from eroding soils in ephemeral tributaries has caused an aggradation of the river bed, principally at and below Albuquerque, with a consequent water-logging of adjoining valley lands.

The worst offender in silting is the Rio Puerco, which joins the Rio Grande approximately midway between Albuquerque and Elephant Butte Dam. From 1885 to 1963 an estimated 600,000 to 800,000 acre feet (740 million to 987 million cubic meters) of soils has washed from the Rio Puerco into the Rio Grande. The Rio Puerco, which comprises 23 percent of the contributing basin in the Upper Rio Grande above Elephant Butte Dam, produces 45 percent of the measured sediment in the main channel but only about three percent of the basin runoff.

The Rio Puerco watershed covers approximately 3.9 million acres (1.6 million hectares). It is a permanent stream only through the upper few miles of its channel. The remaining part and all of its tributaries have ephemeral or intermittent flow.

The southern section of the river extends from Elephant Butte Reservoir in south-central New Mexico to Fort Quitman, Texas, about 80 miles (130 kilometers) southeast of El Paso. This section is divided, physically, by a narrow canyon, or "pass," at El Paso, Texas, and by another engorgement to the north, at Rincon. A fourth division, caused by man, occurs at the El Paso-Hudspeth county lin e. This division will be discussed at length later in this paper. This southern section, including the Mexican counterpart, the Juarez Valley, comprises approximately 175,000 acres (70,000 hectares). Principal crops in this section have been cotton and alfalfa.

Irrigation in the Rio Grande basin above Fort Quitman had its beginnings in prehistoric times. When the Spaniards, under Juan de Oñate, entered the valley in 1598, they found settlements of Pueblo Indians scattered up and down the basin and its adjoining vallets almost up to the Colorado State line. Archaeologists and dendrochronologists argue that these Indians were forced out of Mesa Verde in southwestern Colorado into the less severe conditions in northern New Mexico during an extended drought from 1276 to 1299 A.D. Indications have been found of relatively elaborate canal systems along the Rio Grande and the Rio Puerco. The earlier settlers of this region were the Anasazi, predecessors of the modern Pueblo Indians. They maintained small, settled communities and practiced a primitive form of agriculture.

The low brush and rock diversion dams and canals of the Indians did little to change the ecologic balance. In contrast, the arrival of the Spaniards with their grazing animals may have quickly upset the soil-vegetation equilibrium. For two hundred years Spanish colonists have occupied these valleys lying in the central part of New Mexico. In the first part of the nineteenth century the Spanish were ordered to retire from the area following disturbances caused by roving bands of nomadic Indians, such as the Navajo.

Since 10,000 head of cattle were removed from the Rio Puerco region alone, it may be conceivable that even at that early date overgrazing may have had its beginnings, and there are indications that the land resources had begun to disintegrate. Marauding Indians restricted grazing of sheep to the immediate vicinity of the Spanish communities, and the deterioration of vegetation in these locales may have started the cycle of accelerated erosion.

Although the advent of the Spanish did introduce grazing stock in the region, the deterioration of the land was a relatively slow process. Between the first period of occupancy and 1848, when the region was acquired from Mexico, there were relatively few grazing animals left in the area. After the signing of the Treay of Guadalupe Hidalgo, which ceded the area to the United States, Anglo-Americans with capital entered the country and a campaign was launched to quell the marauding Indians. In 1880 the transcontinental railroad was extended to the Rio Grande valley, creating a means for marketing livestock. As a result an enormous increase in livestock began about 1860, which reached its peak in 1900 when 533,000 animal-units were grazing in the Upper Rio Grande basin in New Mexico.

With the final ending of Indian disturbances in the 1800's, settlers poured into the country, and intensive stock raising combined with severe drought conditions to further aggravate the ecologic imbalance. Ranchers blocked off streams in the upper reaches to supply their herds, and farmers took what water they needed without regard for the people below them on the river. The constant buildup of population added new demands on the already overtaxed water resources.

Continued expansion on the upper reaches of the river led to more and more serious disputes. Mexico was deprived of a rightful share of water and brought increasing pressure to bear on the United States. Finally, the more responsible parties of both countries met to discuss what might be done to alleviate the situation. After extensive investigations by the United States proved the feasibility of creating Elephant Butte Dam and Reservoir, representatives of both countries met, and at a convention ratified an agreement, proclaimed 16 January 1907, whereby Mexico, in exchange for the dropping of all previous claims to water from the Rio Grande, was allotted 60,000 acre feet (2,613,600,000 cu. ft. or approximately 74,300,000 cu. m.) per year. The treaty further states: "In case, however, of extraordinary drought or serious accident to the irrigation system in the United States, the amount delivered to the Mexican Canal shall be diminished in the same proportion as the water delivered to lands under said irrigation system in the United States."

An agreement having been reached on international problems of water allocation in the Rio Grande Valley between El Paso and Fort Quitman, studies on reservoir sites and canals were resumed. Construction was approved in 1910, and Elephant Butte Dam and Reservoir, with a system of diversion dams and canals, was completed in 1916.

When irrigation districts were organized following completion of Elephant Butte Reservoir, contracts were entered into for the construction of lateral distribution canals and drainage systems in addition to storage and drainage works. A critical seepage condition developed as a result of the rising ground-water table, and construction of the drainage system was expanded and expedited. Caballo Dam became justified when it was included as a flood-control unit in the Rio Grande Rectification Project, and part of its cost was allocated to that purpose. It made year-round power generation at Elephant Butte Dam possible and also provided additional project storage.

Caballo Dam and Reservoir were completed in 1938. This reservoir regulates the flow of water to the present canals. It was constructed 22 miles (35.4 km) below Elephant Butte. The dam is of earth-fill construction and the reservoir has a capacity of approximately 344,000 acre-feet (approximately 1,360,000,000 cu. ft. or 424,000,000 cu. m.). This, with the Elephant Butte storage capacity of 2,369,000 acre feet (115,000,000,000 cu. ft. or 3,260,000,000 cu. m.) gives a combined storage capacity for Elephant Butte-Caballo of 2,983,000 acre feet, as originally constructed. Considerable silt was present in the river above Elephant Butte. A great deal of this sediment originates in the Rio Puerco (see above). Some concern was expressed as to the rate of sedimentation in the two reservoirs, and in 1957 a silt survey was made, correcting the actual 1957 capacity of Elephant Butte Reservoir to 2,194,990 acre feet (a loss of 444,010 acre feet) and the 1957 capacity of Caballo Reservoir to 343,990 (a loss of 1,880 acre feet). As of now, total construction costs of the Rio Grande Project are around $28,800,000. This includes the cost of main dams, diversion dams, canals, laterals, and drainage systems from Elephant Butte in New Mexico to the El Paso County-Hudspeth County line in Texas.

The Tree

The tree is the tamarisk, or saltcedar, as it has become known in the Southwest. Saltcedar (Tamarix pentandra), along with others of the tamarisk family, is not a native of North America. Although it is possible that early Spanish explorers and conquistadors who invaded Mexico and made expeditions into the United States between 1540 and 1750 may have been unwitting transporting agents for some tamarisk seeds to North America, no evidence has come to light that any of these established themselves on this continent.

Tamarix pentandra was not mentioned in the United States in early references, but many early specimens can be identified as this species. It may have been one introduced by nurserymen in the early 1800's and called "a handsome shrub, much admired." "French tamarisk, an ornamental shrub" was listed in a catalog of fruits and ornamental trees issued by Lawrence and Mills at the Old American Nursery, Flushing-Landing, near New York, in 1823.

Although it was introduced into this country over one hundred years ago, it has only been in the last thirty years that it has become very much of a nuisance plant in the arid and semiarid regions of the western states. Saltcedar was not considered to be harmful and, indeed, when Dr. J. L. Gardner, Botanist, Agricultural Research Service, U. S. Department of Agriculture, first went to the northwest sector of New Mexico in 1935, saltcedars were being planted along eroding stream banks in an effort to use them as a means of erosion control. The saltcedar is highly water consuming and salt tolerant. It rapidly escaped cultivation and spread from one stream valley to another.

In 1936 the vegetation of the Rio Grande Valley was mapped by the Department of Agriculture during the Rio Grande Joint Investigation. Although saltcedar was present and was mapped in field sheets, no separate classification was established and it was included under the heading "trees-bosque." The rapidity with which it spread is dramatically emphasized by the Bureau of Reclamation survey indicating that in 1947, or over a period of about ten years, some 60,640 acres of land in the valley were taken over by "bosque growth."

In order to understand the enormous impact of this growth it is necessary to refer to the Rio Grande and its problems. As was mentioned in "The River" section of this paper, aggradation of the river bed was caused by deposition of silt from tributaries, principally from the Rio Puerco. The subsequent water-logging of valley lands, while forcing abandonment of agriculture, provided a perfect environment for the water-loving, salt-tolerant saltcedar. The construction of Elephant Butte Dam and, later, Caballo Dam caused a deposition of silt in the stream delta immediately above the reservoirs. Since the reservoir was filled to capacity at only one period, 1941-1942, the extensive deltas below high-water level provide prime areas for the propagation of the plants. In a vicious cycle, the growth of the saltcedars retards the flow of the river, causing additional deposition of silt, accelerating aggradation of the river bed, water-logging of adjacent areas, and increasing favorable conditions for growth of more saltcedars.

A little known, but significant, factor in summation of ill effects caused by this plant in an area of critical water supply is its ability to extract salt from saline ground waters and to exude salt crystals from specially developed salt glands within the plant itself. J. S. Horton, Research Forester, U.S. Forest Service, states that this phenomenon is known in Pakistan, and that certain peoples there gather this salt, chiefly NaCl, for home consumption. The deleterious effect of the "salt whiskers," as John P. Decker calls these exudations, is the pollution of the soil surface with salt extracted from saline ground water. Any flow of fresh water over this soil thus picks up added salt dredged up from a depth which might have made it harmless to plants with shallower roots not extending to the saline water.

The 60,640 acres of saltcedars estimated above were consuming water at the rate of four acre-feet an acre for a total use of 238,700 acre feet a year. This is approximately 45 percent of the total consumptive use in the valley. For comparison with the four acre feet an acre use by the saltcedar, only 1.8 acre feet of water are actually consumed each year in growing an acre of irrigated crops.

Returning to the vicious cycle theme mentioned above, attempts to eradicate the saltcedars along the valleys above the reservoirs, whether by the use of chemicals to kill the plants or by mechanical means, which include mowing the tops or plowing the roots, and rectifying the river channel to restore direct flow, will restore the transportation of sediment into the reservoirs, thus threatening the future of the valley below them. On the face of it, the future of the valley may be compared, up to a certain point, with what happened to the ancient city of Ur of Chaldea. A logical case may be analogous in that at one time the Tigris and Euphrates rivers and their valleys were very fertile. Perhaps overgrazing and the destruction of forests caused silting and aggradation of rivers and canal systems, bringing ultimate failure to irrigation in the valleys.

The most aggravated situation where man has already sought to make most complete use of the water resources and at the same time has failed to exercise care in the use of the watersheds in the southwestern United States occurs in the Rio Grande Valley. Although the facts seem to indicate that a complete integration of efforts along several different lines of conservation practices is necessary to effect a well designed program for irrigation in arid and semiarid regions, this section of the paper will be confined to a single facet of this program: the cause, effect, and suggested control methods of saltcedar infestations.

The accomplishment of phreatophyte control projects on the Rio Grande initially occurred as an incidental part of projects constructed for other purposes. As the phreatophyte problem became more evident and the water supply more critical, more consideration was given to water salvage problems. The first such project undertaken, completed in 1962, consisted of the rehabilitation of the irrigation and drainage systems above and below Albuquerque, New Mexico. River channelization and levee improvements were carried out as part of this project and extended from a point some fifty miles above Albuquerque to Elephant Butte Reservoir, a distance of some 200 miles. This channelization work was carried out to control sedimentation and flooding in the area, and it created a floodway varying in width from about 600 feet in the upstream portion to 1,400 feet in the San Marcial area. This floodway, containing approximately 15,000 acres, must be maintained, and a principal item of maintenance is the control of phreatophyte reinfestation.

In 1957 an experimental program was initiated to clear and maintain a tamraisk-infested area at the head of Caballo Reservoir. The fact that this area lay in a relatively short (some 22 miles) stretch of river channel between Caballo and Elephant Butte made it suitable for a control study. The purpose of the project was water salvage, and was justified on the basis of saving some 14,000 acre feet of water annually by clearing and controlling 6,200 acres. The program has been continued at an estimated annual cost of $20,000. The removal of the saltcedars has not only reduced the water loss but has also improved the grazing capacity of the reservoir area.

The legislative authorization for the work done on the middle Rio Grande also directed that studies be made to determine ways and means of reducing non-beneficial consumption of water in the flood plains of the river and its tributaries above Caballo Reservoir. Following this directive a study of water salvage possibilities was made by the Bureau of Reclamation. Results of this study showed that approximately 53,000 acres of the area were infested with phreatophytes, and that it would be practical to clear some 48,000 acres. Since information on the consumptive use of water by phreatophytes was mostly theoretical, a prototype area was selected about half-way between Albuquerque and Elephant Butte, 6,400 acres of phreatophytes were cleared, and recording of water data was continued. This project is being continued from its initial implementation to obtain an overall, long-range projection of the amount of expected water recovery and its cost. The area is being maintained to prevent regrowth of phreatophytes, and evapotranspiration tanks to measure water use of saltcedars are maintained at Bernardo, New Mexico, at the upper end of the experimental site. For information and comparison figures, reference is made here to estimates in a similar study of saltcedar eradication on the Pecos River, about 40,000 acres of heavily infested areas in the Pecos River Valley, between Acme, New Mexico, and Mentone, Texas. The studies indicate an average annual water loss prevention over the next fifty years of about 150,000 acre feet at a cost of about $4.75

per acre foot. Assuming the water is used for irrigation, the benefits are estimated to vary from $20.40 to about $58.30 per acre foot depending on where the water would be used. It would be reasonable to assume that present studies being made on the Rio Grande will show quite similar results.

The time factor for the presence of saltcedars in the Rio Grande Valley in relation to the total time the area has known irrigated farming is indeed minuscule. For unknown hundreds of years the valley has known farming activities. And only during an extremely short period of that time, roughly thirty years, has the saltcedar been known as a trouble maker in the area. Concentrated efforts at control have been carried out for an even shorter period of time and long-range studies, taking into consideration the many complex problems involved are, in realtiy, only just beginning. Some of the methods which have been used and are being used for elimination and control of saltcedar are detailed here.

The U. S. Bureau of Reclamation began experimenting with chemical control of tamarisks in 1948, spraying 200 acres of the plant with a formula of 2,4-D at the rate of one pound per acre. One hundred acres of this area were again sprayed in 1949. Of the plants receiving the two applications, up to 85 percent were killed, and it was hoped that a relatively simple means had been found to control saltcedar. However, in 1951, 2,600 additional acres of adult saltcedars were sprayed, using a similar formula with new herbicides added. The results did not substantiate the marked success originally encountered. Subsequent experiments have not proved that chemicals alone can solve the problem.

Since these earlier experiments, the Bureau of Reclamation has continued its exploration and evaluation of various methods of phreatophyte control. A combination of mechanical and chemical means is being used, with tests of new chemicals proving to be more and more efficacious. A process of mowing followed immediately with a spray application of eight pounds of silvex ester per acre in diesel oil has reduced stands as much as 83 percent.

Costs and methods of clearing saltcedar vary considerably depending on density of plants and type of equipment used. Limited cost for clearing approximately 6,000 acres in the Caballo Reservoir area, as mentioned above, averaged approximately $20 per acre, but the cost of clearing 6,400 acres midway between Elephant Butte and Albuquerque was $45 per acre. It must be pointed out, however, that the Caballo tract was done by Bureau of Reclamation personnel and equipment, while the middle reaches tract was accomplished by contract. Also, the density of the stand of saltcedar and the texture and stability of the soil differed in the two areas, so this must be taken into account when comparing costs.

Various methods of mechanical control of saltcedar infestations have been tried. The most effective equipment for complete eradication is the root plow. As used by the Bureau of Reclamation on the Rio Grande, a 12-foot root plow mounted on a crawler tractor is used. Other machines which have been used effectively for initial clearing are the rock rake, bulldozer, and rotary mower. Another machine which has not been used to date but is worthy of consideration is the tree crusher.

The root plow attached to a D-8, or comparable size, tractor may be used effectively to remove growth ranging up to 15 feet in height even though the plant may be relatively dense. Additional expense will be required to stack and burn the plants which are left on the ground. With the use of the root plow, the plants are cut about 10 to 12 inches below the surface of the soil and the residue is deposited on the surface. Cost of this method of treatment was found to be about $20 to $25 per acre, not including the cost of stacking and burning the residue. The disadvantage of this method is that it leaves the soil in an extremely soft condition and destroys the majority of any grass cover. Also the operation is not effective when the water table and soil moisture are high.

A rock rake has also been used for removal of large plants. and dense growths. This rake fits on the front end of a D-8, or equivalent size, crawler tractor. The teeth on the rake operate below the surface of the soil and the majority of the plants are uprooted. The average operating cost of this equipment, like that of the root plow, is about $20 to $25 per acre, not including stacking, burning, overhead, and so forth.

The Marden Brush Cutter has been suggested as a possibility for preliminary clearing. This machine is similar to a sheep=foot roller, but with cutter blades welded to the drum instead of "sheep feet." The machine is pulled by a D-8 tractor and it is estimated that it should be capable of crushing and cutting plants 12 to 15 feet in height and 6 to 8 inches in diameter. It is believed, however, that considerable debris will remain on the top of the ground, requiring additional cleanup prior to operation and maintenance on the area.

An 84-inch rotary mower has been found quite practical for this type of work. Powered by a 45 horsepower, wheel-type tractor, it can be used effectively for cutting brush 6 to 8 feet high and up to two inches in diameter. The cost of this machine, used for clearing, averaged $7 to $9 per acre at Caballo Reservoir. This did not include overhead or supervisory expenses.

The tree crusher, described as a product of the Le Tourneau Company, weighs approximately 55 tons. It has not been used on any phreatophyte area as yet, and data are from the manufacturer's representations. It is said to be capable of crushing plants up to 12 or 15 inches in diameter and completely destroying small branches and stems. The machine can only be used effectively in an area where the soil is firm and the water table is not too high. It is not known what effect the use of this machine would have on the surface after the phreatophytes are knocked down. If the majority of the trunks are disposed of and if the small branches and stems are completely buried, almost any type of mechanical equipment could be effectively used for maintenance. If considerable debris is left on the surface, however, it would be necessary to rake the area and burn the debris prior to operation and maintenance. No field data on cost per acre for operation of this machine are available.

After an area has been completely cleared of saltcedars, the problem of maintenance remains. Regardless of the type of clearing operations resorted to, there will always be a certain amount of regrowth and reinfestation. Annual maintenance of a cleared area is an ever-present problem. While encouragement of grass-type vegetation will do much to inhibit the regrowth of woody plants, both chemicals and machinery are necessary.

The root plow, described above, can be used effectively for curtailing regrowth, particularly when a heavy reinfestation is encountered. The principal objection to its use in maintenance is that it destroys any grassy vegetation in the area, leaving the land subject to wind erosion. The optimum use of this equipment is in a dry soil. In moist or wet soil many of the plants will be transplanted and immediately start growing.

A Towner Disc, powered with a D-8 tractor or comparable power source, is of value in smoothing up the area in order that a more efficient and effective machine can operate. In many cases, the area will require disking in cross directions to obtain the desired smoothness. Estimated average cost of operation is $10 to $11 per acre.

The 84-inch rotary mower, mentioned above, has been a popular implement of maintenance on the Rio Grande, although its use is somewhat limited. The terrain must be relatively smooth and free of stumps and large sticks for effective operation. For relatively large acreages, an average cost of $2 per acre was estimated, which cost includes depreciation, repairs, fuel, oil, and labor.

In using chemicals to control regrowth, a ground spray rig or a helicopter may be employed. The cost of helicopter spraying has been estimated as $10 to $12 per acre, including furnishing the helicopter, chemical, mixing, and flagging. Helicopter spraying may be accomplished on an area which is left xxx relatively uneven with considerable debris on top of the surface. However, extreme care must be employed when using this method in the vicinity of farmsteads and susceptible crops. By using an invert emulsion chemical applications of herbicides may be made with a minimum of drift and with the expectation that the chemical will fall where expected.

The cost of operating a ground spray rig, including the tractor required for pulling, will average approximately $5 to $7 per acre. Cost of chemicals, although varying to some extent with the type of chemical used and the rate of application, should be about $3 per acre. Thus, it would appear that the cost of spraying, either by helicopter or by ground rig, should average approximately $10 per acre, and it is believed that one spraying annually would adequately control the regrowth in an area. It must be pointed out that the above proces are from the Bureau of Reclamation Report on Clearing and Controlling Phreatophytes Cost Data survey dated November, 1963, and there may be some cost adjustments necessary now.

Various chemical herbicides have been used in experiments on the control of saltcedars throughout the Southwest and West. In Wyoming basal spray applications of a 1:1 mixture of the esters of 2,4-dichlorophenoxyacetic acid and 2,4,5-trichlorophenoxyacetic acid at 2- and 8-percent concentrations provided very effective control when the chemical was applied in mid-summer.

Research in New Mexico showed basal and stump applications of ester and oil-soluble amine formulations of 2,4,5-trichlorophenosypropionic acid (silvex) to be effective for control of saltcedar. Trees with trunks two inches or larger in diameter were harder to kill than smaller trees, and retreatment was necessary. Spraying the lower two feet was no more effective than spraying the lower foot. Cutting the larger tree and spraying the stump increased effectiveness.

Application of 3-phenyl-1, 1-dimethylurea (fenruon) pellets at 10, 15, and 20 lbs. per acre active ingredient in April gave 97-100 percent control of saltcedar in Wyoming. In New Mexico results of April applications of six granular herbicides indicated that 2-methoxy-3, 6-dichlorobenzoic acid (dicama) killed a high percentage of plants. Rates of 5 and 20 lbs. per acre active ingredients were used. Another herbicide, 4-amino-3, 5, 6-trichloropicolinic acid (picloram) was only moderately effective at the higher rate. Applications of soil-spray herbicides for control of saltcedar over a 2-year period showed that only one herbicide, 3-(3,4-dichlorophenyl)-1,-1-dimethylurea (diuron) plus dodecyl ether of polyethylene glycol (Surfactant WK) produced measurable results after sixteen months. Even so, this treatment did not appear promising.

As early as 1948, control studies using foliage-applied herbicides were conducted on saltcedar in Arizona, Wyoming, and New Mexico. Four years of research in New Mexico have shown that one application of 2 lbs. per acre of silvex ester and 2 lbs. per acre of picloram to saltcedar gave promising results. Mowing in the winter and spraying the resulting regrowth in June gave better results than spraying unmown plants.

Preliminary results (report is dated 1966) of saltcedar control experiments conducted in New Mexico indicate that, although the herbicide rates are rather high, dormant-applied treatments are effective. Mowing saltcedar in February and spraying the freshly mowed stumps with 8 lbs. per acre of silvex ester in 50 gpa of diesel oil reduced the stand 72 percent compared with 42 percent for sprayed but unmowed plants.

Spraying saltcedar on a ditch bank with 8 lbs. aehg (pounds acid equivalent per hundred gallons of diluent) of silvex in diesel oil at 100 psi pressure killed 95 percent of the plants treated. Spraying was done from one side with a high-volume sprayer and a hand gun.

The County

Some forty miles below the City of El Paso, Texas, a political boundary intersects the United States portion of the valley of the Rio Grande. This is the lowest of the chain of valleys of the Upper Rio Grande. The bottom of the barrel. And it is almost literally just that. On the United States side of the river, the channel of which forms the international boundary between Mexico and the United States, the Quitman Mountains reach the river, and the mountain range, a relatively low one, continues into Mexico. The river is confined to a narrow gorge, or box canyon, at this point. It is this gorge, sometimes identified by the name of Fort Quitman, after an early United States Army post at the upstream end of the gorge, that terminates, geographically, what is referred to as the Upper Rio Grande.

Geologically speaking, the river valley is a unit, from the box canyon of "the pass" at El Paso del Norte to the gorge at Fort Quitman. Since the Spanish first reached the valley, under Cabeza de Vaca in 1536 and under Coronado in 1540, it has had a long history of occupation and irrigation development. The indigenous tribes occupying the valley when the Spanish arrived had attained but a low degree of culture and engaged in little or no agriculture. The actual agricultural history of the valley should probably begin in 1598 with the journey of Juan de Oñate who continued up the river to colonize what is now New Mexico. A mission was established at Paso del Norte in 1659, and the Spanish used the settlement which grew up around the mission (and which is now Ciudad Juarez, Mexico) as a way station on their travel route to and from Mexico in their conquest and colonization of northern New Mexico during the 17th and 18th centuries.

Slowly but steadily the colony grew. Retreat of the Spanish conquerors and their Indian converts to Paso del Norte in 1680 when driven out of New Mexico by the Pueblo Indians in revolt resulted in the establishment of several settlements below Paso del Norte, some of which, Ysleta and ~~Socorro are on the north or United States side of the river~~

Socorro, are on the north, or United States, side of the river, and are still in existence.

Infiltration of the area now comprising the state of Texas by Americans, a majority of them from Tennessee, began in the early 1800's. Continuing friction between these infiltrators and Mexicans already present in the area developed into open hostitlities, which eventually resulted in a treaty, concluded at Guadalupe Hidalgo February 2, 1848, between Mexico and the United States. This treaty located the international boundary of the two countries in the channel of the Rio Grande, dividing the valley below El Paso del Norte into two sections. A further political subdivision of this valley occurred in 1917, as a result of the completion of Elephant Butte Dam. The ~~xxxx~~ establishment of the Rio Grande Project under the Bureau of Reclamation opened the way for a new agriculturel era in the valley below the dam. Water improvement districts were delineated, and the El Paso County Water Improvement District No. 1 was organized in 1917. As, in the natural course of events, areas closer geographically to the reservoir developed utilization of water earlier, inhabitants of the area at the lower end of the valley organized politically and detached the area from El Paso County, forming Hudspeth County, in 1917.

Increased usage of river water upstream from Hudspeth County led to the organization of the Hudspeth County Conservation and Reclamation District No. 1 in 1924. The district, comprising 18,330 acres, received Rio Grande Project operating waste and drainage flow water reaching the lower end of the Project under a Warren Act (1911) contract. Original construction was financed by a bond issue of $700,000. From 1924 to 1956 additional sums increased total construction funds to $2,200,000. These figures, and the facts that the funds were raised through action of this district, acting independently, were to play a crucial part at a later date when, with the completion of Caballo Dam and Reservoir, the areas below the reservoir, as far as the El Paso-Hudspeth County line were formed into irrigation and improvement districts under the Bureau of Reclamation.

Contracts providing for the construction, operation, and maintenance, and repayment of the costs on the irrigation system were entered into with the Elephant Butte Irrigation District for the New Mexico portion of the Project area of 90,640 acres of water-right land with a total construction cost repayment obligation of $5,698,012, and with the El Paso County Water Improvement District area of 69,010 acres of water-right land with a total construction cost repayment obligation of $6,746,111.

The Hudspeth County Conservation and Reclamation District No. 1 was seriously concerned with the formation of these up-river water improvement and irrigation districts at this time. By joining the up-river districts and allowing its independent district to be absorbed as a district under the Bureau of Reclamation, the Hudspeth District would be allotted a proportionate share of water released for irrigation at Caballo Dam. However, the District had a complete system of canals, check-dams, laterals, and drains at this time, and

and was indebted for this system. The question arose as to whether or not to increase the indebtedness by assuming a portion of the upstream costs of construction. The District was operating, under the Warren Act, on waste and drain water at the time.

Perhaps the fact that the period 1941-1942 was a period of abundant flow in the river, including the fact that Elephant Butte Dam overflowed into its spillway for the only time in its history in 1942, gave confidence to the water-users in Hudspeth County. There was an adequate supply of water of a saline content reasonably acceptable, and the drains were functioning, carrying excess salts down the river. In any event, water-users in the District, taking into consideration the facts that (1) the District was already in debt for its own irrigation system, (2) it was assured, under the Warren Act, of all waste and drain water released by its immediate upstream neighbor, El Paso County Water Improvement District, (3) at the particular period of time of formation of Districts under the Bureau of Reclamation there was ample flow of water in the river, and (4) assumption of further indebtedness for water use would increase the cost per acre-foot to an alarming degree, voted not to join their upstream neighbors in operating under the aegis of the Bureau of Reclamation, but to continue as an independent district.

It is a highly controversial question, whether or not this decision would have affected the subsequent deterioration of the water situation in the Hudspeth County district. Many factors were involved, including what is probably the main one of an extended period of dry, or subnormal, water flow in the river. The accompanying chart of Rio Grande discharge at San Marcial, New Mexico, at the head of Elephant Butte Reservoir, shows a gradual decrease in annual discharge from a high in 1925 of approximately 900,000 acre feet to approximately 680,000 acre feet in 1967. As these figures are an indication of the progressive mean, including carry-over from excessive wet and dry cycles, it might be significant to point out that the discharge for the year 1967 totaled approximately 390,000 acre feet.

The "Long Range Program and Plan" of the El Paso-Hudspeth Soil and Water Conservation District No. 205, State of Texas, prepared December 1966, shows Hudspeth County District water allotment as in Table 1. The report states: "Much of the land in the Hudspeth County Conservation and Reclamation District has not been irrigated continuously since the beginning of the drought of the 1950's."

Mac Guest, present (1968), manager of the District, generously devoted an entire day escorting me on a tour of his District. During this tour he told me that "Caballo Dam ruined the Hudspeth County Conservation and Reclamation District." This seemed a startling and provocative statement until I learned more about the situation, and the reasoning behind his words. Actually it was a series of events, some unforeseen at the time, and some, such as droughts, a phenomenon of nature beyond human control at the present time, that caused the present distress of the District. In general, the creation of Caballo Reservoir and the

Table 1. Hudspeth County Water Allotment

Year	acres in cultivation*	Acre feet of water at heading	Acre feet per acre irrigated
1950	17,329	42,771	2.47
1951	17,752	32,289	1.82
1952	18,207	38,125	2.10
1953	12,127	28,264	2.33
1954	12,127	3,381	0.28
1955	5,455	174	0.03
1956	4,477	none	none
1957	3,860	759	0.20
1958	4,023	18,215	4.53
1959	6,992	37,869	5.41
1960	8,907	57,823	6.49
1961	9,661	39,962	4.14
1962	11,404	68,326	5.99
1963	11,268	41,703	8.70
1964	8,421	2,213	0.26
1965	8,123	8,060	0.99

* Total acres in the district: 18,432.

and the subsequent development of more stable irrigation conditions downstream allowed increased acreage to be brought under proper irrigation, and with the favorable water-supply situation prevailing in 1941, the decisions of the Hudspeth water users were readily ~~understand~~ understandable. They had all of the waste and drain waters from the districts up-river, and a satisfactory out-flow at Fort Quitman assured that their own drains were functioning. They already had their own irrigation system, and were paying on their bonded indebtedness.

One fact was possibly overlooked, or if it was known, insufficient attention was paid to it. As has been mentioned above, the Upper Rio Grande is considered to terminate at Fort Quitman, where the Quitman Mountains to the north with their extension into the south form a box canyon. The river, meandering across the alluvial valley downstream from El Paso, is throttled by the rocky barrier of the mountains, through which it has laboriously cut its course. From its earliest agricultural use to the present time, what is termed a normal, or mean, flow has allowed a constant discharge over the sill, or dike, closing off the lower end of the basin.

Increasing use of irrigation water above Fort Quitman and, indeed, throughout the entire Upper Rio Grande adds increasing amounts of salt to the river flow downstream. In periods of normal flow this salt burden is constantly shifted downstream through proper functioning of adequate drainage systems. Obviously, the farther downstream the water flows, the greater its salt burden. But in times of drought, drains fail and the small amount of water available is increasingly vulnerable to evapotranspiration. The upstream salts are left in downstream ground water. And when ground-water flow is interrupted by a rock barrier, as is the case of the Fort Quitman engorgement, the salt content builds up at a continuous rate. As the surface flow decreases, water-users are forced to drill wells to augment their water needs. Wells become increasingly salty. I spoke to a farmer in Hudspeth County who had just completed the drilling of a new well. He told me that his new well showed a salt content of 22 tons per acre foot! Worthless.

The figures in Table 2 are from Research Report No. 106 of the U.S. Salinity Laboratory, dated 1963. Tonnage of salt crossing El Paso-Hudspeth County line is 79% of tonnage below Caballo Dam. If output is corrected for tonnage of salt diverted into Mexico, the percentage becomes 93. There is no drainage from the Mexican side. This water is completely dissipated.

Prior to 1951 there was, apparently, according to District reports, an adequate supply of surface water. To be sure, the saline content of waste and drain water from upstream was quite high, but the Hudspeth drains were working and salinity in the soils could be kept at a level at which some of the more salt-tolerant crops could be raised successfully. Cotton, both long and short staple, was and is the predominant crop in the area, with alfalfa ranking second. In the year 1950, 12,601 acres were planted to cotton, 3,953 acres to alfalfa, with other crops being planted on 775 acres.

Table 2. Volume of Water and Tonnage of Salts Constituents Passing Control Stations (1963)

	County Line	County Line to Fort Quitman gain or loss	Fort Quitman
Discharge, acre feet	71,966	-48,605	23,361
Dissolved solids, tons	246,124	-119,274	126,850
Calcium, Ca, tons	18.791	-8,846	9,945
Magnesium, Mg, tons	4,451	-1,766	2,685
Sodium, Na, tons	56,952	-27,943	29,009
Bicarbonate, HCO_3, tons	8,988	-4,278	4,701
Sulfate, SO_4, tons	69,240	-40,798	28,442
Chloride, Cl, tons	73,632	-29,456	44,176
Nitrate, NO_3, tons	303	-244	59
Total Ions, tons	232,357	-113,331	119,026

As the dry cycle set in, less and less water was available, causing less acreage available for cultivation. By 1955, cotton acreage was down to 3,254, alfalfa acreage dropped to 1,163, while 1,038 acres were devoted to other crops.

The coming of the dry years forced the landowners to drill wells to augment the vanishing supply of surface water. Since 1951, 149 individually owned irrigation wells have been drilled. The 1955 figures indicate that the average depth of these wells was 100 feet. Average discharge was 650 gallons per minute. Immediately, however, difficulties were encountered. The bottom of the barrel was collecting a tremendous amount of salt, and with the high cutoff sill at the Quitman Mountains, most of this exceedingly saline water was trapped, and the salt content was increasing. Some fifty of the wells drilled, at an average cost of $6,000 each, had been abandoned by 1955, due to poor quality of water. The remaining wells were pumping, in 1955, an average of 6.17 tons of salt per acre foot of water. This water could not be used over any extended period of time.

By the end of 1955 less than one third of the irrigable land in the District was being cultivated. Most landowners ~~who remained took~~ moved their farming interests to other areas. Some of those who remained took jobs nearby and sold cotton allotment acreage in order to keep up land payments and taxes. Farm population of the District under what was called normal conditions in 1956 was estimated to be 4,500, but population in that year was estimated to be 1,000. The combined population of the four small communities in the District, Fort Hancock, Acala, McNary, and Esperanza, dropped ~~in population~~ from 700 to 400.

A farm of 198.1 acres in the District, valued at $1,000 per acre before dry years and salt problems occurred, was sold in 1967 by the Federal Land Bank for $10,000, or less than $50 per acre. In order to hold his irrigation water rights on a farm in the District consisting of, for example, 1,000 acres of irrigable land, the farmer must disc the entire 1,000 acres yearly, even though his water allotment, when he receives it, will only be sufficient to farm 250 acres, or one quarter of his farm. If he fails to disc his entire irrigable acreage, it reverts to rangeland, and his water allotment is reduced to the actual acreage he has disked. This, of course, adds to his per-acre costs of farming.

In 1968, only enough water was available to successfully farm approximately 6,000 acres of the Dsitrict's irrigable acreage of 18,342. Most wells and all drains at the bottom of the system are averaging approximately eight tons of salt per acre foot. With the present agricultural load on the river upstream, even a return to what is calculated to be a normal flow in the Rio Grande will not solve the Hudspeth County District's water problems.

The only solutions even vaguely considered possible to the District's dilemma are the importation of water from another source or devising some means of desalinating the ground water.

The Country

Cabeza de Vaca and Coronado were the first Spanish explorers to reach the Juarez Valley. But it was not until sixty years had passed and Juan de Oñate, on his way to colonize the upper reaches of the Rio Bravo del Norte, in what is now the northern section of New Mexico, that agriculture really started in the valley. The Indian tribes these explorers encountered were primitive, indeed, and were primarily hunters and gatherers.

However, with the advent of Spanish colonizers, farming did spring up in the valley. The colonists found ample room for farming, and an ample flow of waxw water in the river. The mild climate, with a long growing season, was not unlike that of their native Spain. Brush and rock diversion dams were built, and the wild (unregulated) flow of the river was led through acequias, or canals, to the riparian lands. What if spring floods did destroy the crude dams? The colonists rebuilt them, repaired the canals, and soon were busily growing the next year's crops.

Slowly over the course of the centuries, but always increasing, the farms grew in the valley. These were peaceful and prosperous times for the inhabitants, and the agricultural colony continued to expand until, at the beginning of the present century, there were approximately 25,000 hectares (about 61,800 acres) under cultivation in the valley. This, it should be pointed out, is the area lying south of the Rio Grande, across from the two districts to the north--El Paso County and Hudspeth County.

Rapid development of agriculture upstream from El Paso during the latter part of the 19th century created more and more demands on the resources of the river. Acute water shortages were suffered by the farmers of the Juarez Valley, and strong disputes originated among the water-users on both banks of the stream, in an effort to utilize the reduced flow which the Rio Grande was carrying. Mexico was deprived of a rightful share of this flow and brought increasing pressure to bear on the United States.

The situation became more and more serious until the more responsible parties of both countries met for the purpose of resolving the difficulties. An agreement was ratified and proclaimed January 16, 1907, giving Mexico the right to divert water from the Rio Grande for agricultural purposes up to 74 million cubic meters (60,000 acre feet) per year, which would serve to irrigate the lands open to cultivation at that time. This set amount of water allowed as a maximum amount of flow to be diverted in any one year necessarily limited any future increase in irrigation from gravity flows.

Although this agreement was ratified in 1906, the completion of Elephant Butte Reservoir in 1916 with its subsequent development of the Rio Grande Project on the United States side of the border did not seriously restrict use of water in the Juarez Valley. It was not until the completion of Caballo Dam and Reservoir and the formation of irrigation districts under the Bureau of Reclamation in 1938 to 1941 that curtailment of water was felt in the Mexican valley. At that time there were approximately 18,500 hectares under cultivation in the valley.

From that time the farmers in the valley initiated drilling of wells, relatively shallow, for the purpose of withdrawing from the ground water necessary to supplement the irrigation of the area already under cultivation. Subsequently the Federal Government, through various interested agencies, assisted in this program.

From 1937 to date the volume of water delivered to the farmers of the Juarez Valley has varied between an annual minimum of nine million cubic meters to a maximum of 74 million, resulting in an average of approximately 35 million cubic meters. (The 1906 agreement carried the provision that in case of extraordinary drought or serious accident to the irrigation system in the United States, the amount delivered to the Mexican Canal would be diminished in the same proportion as the water delivered to United States lands.) Pumping ground water has varied in accordance with the volume of water delivered by the United States. It is considered that an average of 90 million cubic meters of ground water per annum are being withdrawn to supplement the irrigation of approximately 11,000 hectares, this being the area presently under cultivation.

Water used for irrigation in the Juarez Valley varies in quality in accordance with the total salt content. Surface water from the Rio Grande has a minimum salt content of 900 parts per million, while the ground water varies between 900 and 2500, depending on the zone of extraction. Extreme salinity, such as is encountered in Hudspeth County, Texas, is nowhere near as noticeable in the Juarez Valley. It has been suggested that closer proximity of low mountains acting as a watershed on the Mexican side may add considerable quantities of water with relatively low saline content to the ground water available to the valley. Thus it might be presumed that quantity rather than quality of water is the major limiting factor in the future development of the valley.

The reduction of the Rio Grande water available for agriculture after the construction of Elephant Butte and Caballo dams brought about a reduction in irrigated areas, as has been stated, from 18,000 hectares to only 11,000 hectares, the present average. Light-textured soils with good vertical drainage have been preserved from salt saturation due to the excess water applied to satisfy the leaching requirements, but heavy-textured soils of difficult drainage have suffered a progressive salt saturation, due mainly to the lack of sufficient water and to the poor quality of the well water.

The valley farmers, thanks to new cultivation techniques, fertilizers, and the use of a better variety of seed, have improved their lot year by year, and once the Federal Government has carried out the consolidation of the district, yields can be increased, bringing about a rise in the farmer's economic level, to a level equal to that of their neighbors in the El Paso valley.

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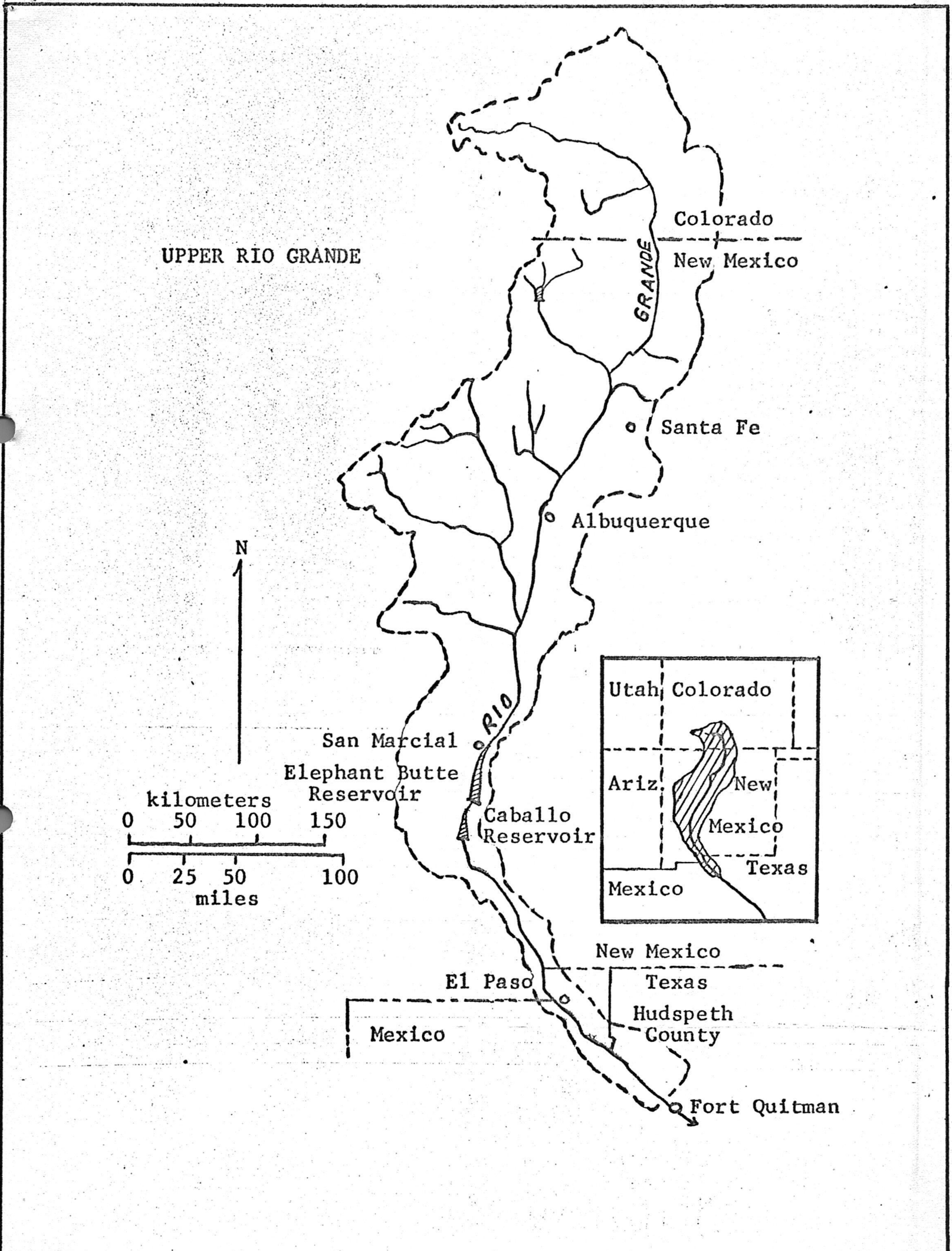
UPPER RIO GRANDE
Colorado
New Mexico
GRANDE
Santa Fe
Albuquerque
N
RIO
San Marcial
Elephant Butte
Reservoir
Caballo
Reservoir
kilometers
0 50 100 150
0 25 50 100
miles
Utah
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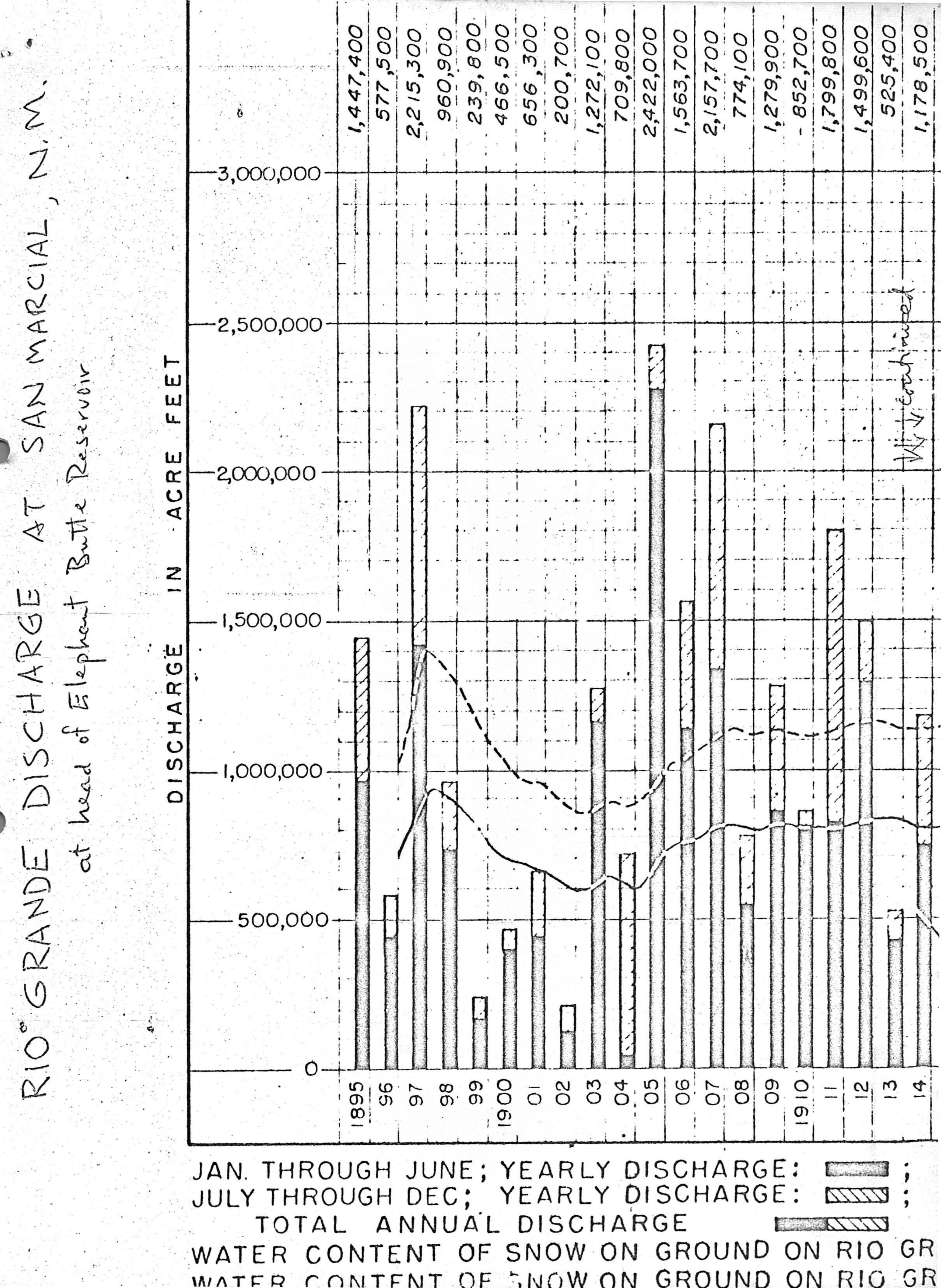
Ariz.
New
Mexico
Texas
Mexico
New Mexico
Texas
El Paso
Hudspeth
County
Mexico
Fort Quitman


RIO GRANDE DISCHARGE AT SAN MARCIAL, N.M.
at head of Elephant Butte Reservoir
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709,800
2,422,000
1,563,700
2,157,700
774,100
1,279,900
852,700
1,799,800
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TOTAL ANNUAL DISCHARGE
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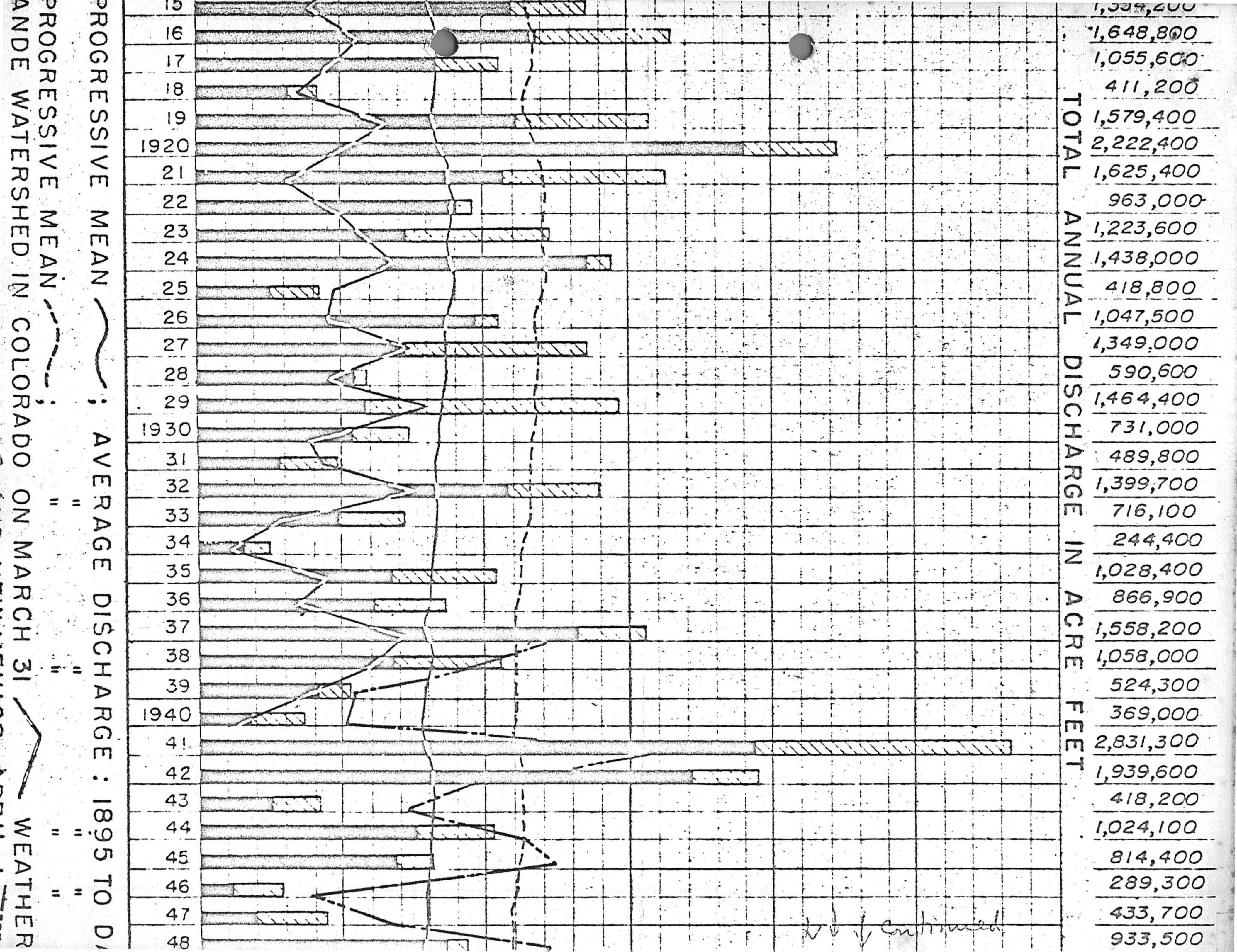
WATER CONTENT OF SNOW ON GROUND ON RIO GR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18 411,200
19 1,579,400
1920 2,222,400
21 1,625,400
22 963,000
23 1,223,600
24 1,438,000
25 418,800
26 1,047,500
27 1,349,000
28 590,600
29 1,464,400
1930 731,000
31 489,800
32 1,399,700
33 716,100
34 244,400
35 1,028,400
36 866,900
37 1,558,200
38 1,058,000
39 524,300
1940 369,000
41 2,831,300
42 1,939,600
43 418,200
44 1,024,100
45 814,400
46 289,300
47 433,700
48 933,500

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" 948,948 A. F.

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RIO GRANDE PROJECT
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